Developing weed management strategies within phase pasture systems in the northern wheatbelt of Western Australia to benefit subsequent crop

PROJECT DETAILS

PROJECT CODE: DAW620

PROJECT TITLE: DEVELOPING WEED MANAGEMENT STRATEGIES WITHIN PHASE PASTURE SYSTEMS IN THE NORTHERN WHEATBELT OF WESTERN AUSTRALIA TO BENEFIT SUBSEQUENT CROP

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Summary

This project researched the use of phase pasture systems in the northern wheatbelt of Western Australia (WA), with an emphasis on the management of herbicide resistant weeds. Experiments were conducted on phase pasture cropping rotations, weed control options within pasture phases, herbicide tolerance of new pasture legume varieties and pasture establishment techniques. Short periods of pasture were shown to be a profitable strategy for weed management in grain production systems. Project outputs were in the form of information which was extended to growers through field days and conferences and published in several reports and conference proceedings.

Report Disclaimer

This document has been prepared in good faith on the basis of information available at the date of publication without any
Conclusions

The inclusion of a pasture phase to break up intensive crop rotations (like wheat-lupins) is an effective and profitable strategy for managing troublesome crop weeds, particularly those that have developed resistance to one or more herbicides. This is a major issue for the northern wheatbelt of WA.

The persistence of hardseeded annual pasture legumes in self-regenerating rotations is questionable when high levels of weed control need to be achieved in every season. Where pasture seed set is compromised and regeneration after several years of cropping is required, legume densities are unlikely to be high enough to provide a productive pasture. Casbah biserrula and Charano yellow serradella offer the best prospects for success in these systems because of their capacity to form persistent seed banks and both species allow for novel weed control strategies to be employed in the pasture phase. Preferential grazing in biserrula (without herbicides) and the option to use non-selective herbicides in regenerating yellow serradella pastures will contribute to an integrated approach for weed management.

Sacrificial legume pastures of one to three years duration provide the best means of achieving a pasture phase in which high levels of weed control and a high legume component for rotational benefits can be achieved. It is a simple system to manage and weed control is less likely to be compromised. Cereal grain yields were consistently higher in the rotations with sacrificial pastures (of at least two years duration) as a consequence of more effective annual ryegrass (*Lolium rigidum*) control. The package should include the following elements: soil disturbance to encourage weed germination in as many years as possible and weed seed-set control in all years - the most effective technique being hay freezing (or brown manuring). For pasture phases of two years duration, sowing a legume in the second year is likely to be the most successful strategy and provide the greatest benefits to the subsequent cropping phase.

Livestock need to be included in these systems in order for them to be economically viable and their profitability is reliant on a buoyant meat market. The cost of pasture establishment and management and the opportunity cost of having the pasture phase out of production for cropping necessitate the use of livestock to generate an income stream on that part of the farm.

One area of concern highlighted by this project is the ability of annual ryegrass populations to quickly return to very high numbers once there is a return to cropping. This quick recovery of weed populations in the cropping phase highlights the need to control annual ryegrass in every phase in every year. Integrated systems with the complete range of weed control options in the cropping years (e.g. trifluralin, targeted burning, seed catching, etc.) will be required.

Annual ryegrass in the northern wheatbelt of WA has a capacity for substantial levels of dormant seed to carry over from year-
to-year. This level of dormant seed would seem to be higher than the 15-20% figure often referred to after one summer, with some seed possibly carrying through to the third season. This carryover of dormant seed appears to assist the rapid recovery of annual ryegrass numbers in the cropping phase.

Herbicide tolerance varied widely between species of pasture legumes, although safe options exist for most varieties. Growers and agronomists need to make careful decisions when choosing herbicide treatments.

**Recommendations**

Sacrificial legume pastures of one to three years duration provide the best means of achieving a pasture phase in which high levels of weed control and a high legume component for rotational benefits can be achieved. It is a simple system to manage and weed control is less likely to be compromised. The package should include the following elements: soil disturbance to encourage weed germination in as many years as possible and weed seed-set control in all years - the most effective technique being hay freezing (or brown manuring). For pasture phases of two years duration, sowing a legume at high density in the second year is likely to be the most successful strategy and provide the greatest benefits to the subsequent cropping phase.

The effectiveness of spray topping for weed seed-set control can be variable with the timing of application and seasonal conditions causing the maturity of weeds to be staggered. If spray topping is to be utilised, two applications - one at early flowering and one at late flowering - should be considered, as this technique greatly reduces the risk of failure. Hay cutting was also effective for prevention of weed seed-set, but should be combined with hay freezing to control re-growth.

At high annual ryegrass populations, a single year of annual ryegrass control is insufficient to reduce the seed bank to a level suitable to begin another cropping phase. At least two - and potentially three - years of pasture will be required. When annual ryegrass seed banks are reduced and the cropping phase begins, it is still necessary to minimise annual ryegrass seed-set as much as possible, or annual ryegrass numbers will rapidly recover to levels that can impact on crop yields - in some cases with favourable seasons within one year.

For phase pastures to be economically viable, it is necessary to include livestock in the system to utilise these pastures. Each phase of the rotation needs to be productive in its own right. While adding significant benefits to the rotation as a whole, it is difficult to justify the inclusion of phase pastures without achieving an income from livestock. The inclusion of a pasture phase without livestock creates a drain on the productivity of the rest of the farm, usually resulting in a negative financial position.

Grazing can be utilised as an effective weed control strategy in pasture species, such as biserrula, that sheep actively avoid at key times during the growing season. High levels of weed control can be achieved in biserrula dominant pastures by grazing through spring. This strategy needs further development, as issues concerning the incidence of photosensitivity in this species need to be resolved.

Delayed germination in some legumes has created an opportunity for weed control in regenerating pastures using an early application of non-selective herbicide. It relies on the fact that most of the weeds will emerge (and be controlled) before the pasture legume germinates. Early indications are that this technique can be successful in Eastern Star clover and yellow serradella, but it needs further validation and refinement on a paddock scale before it can be promoted as an effective weed management tool.

Herbicide tolerance varied widely between species of pasture legumes. Growers and agronomists need to make careful decisions when choosing herbicide treatments.

**Outcomes**

Economic outcomes

This project has demonstrated that the use of pastures within a cropping rotation provides alternative options for weed control that can be at least as profitable as existing continuous cropping systems. Short term phase or sacrificial pastures appear likely to be easier systems to manage than self-regenerating pastures when the focus is primarily on seed-set control of crop weeds such as annual ryegrass and wild radish (*Raphanus raphanistrum*).
Economic analysis carried out as part of this project identified that several pasture systems were as economically viable as continuous cropping in a wheat-lupin (WL) rotation. The WL rotation resulted in a 10 year cumulative financial position Net Present Value (NPV) of $243,000 compared to a self-regenerating pasture-pasture-wheat (PPW) rotation at $655,000 and a phase rotation of pasture-pasture-pasture-wheat-canola-wheat-lupin-wheat (PPPWCWLW) at $445,000. Once lupin yields become affected by weed competition in a herbicide resistant situation, pasture rotations become an even more economically viable system (WL rotation with a 20% reduction in lupin yields at -$313,000) maintaining the farm in a positive financial position. The implications at an industry level are a shift towards slightly lower cropping percentages, while maintaining or increasing whole-farm profitability. The capacity for this transition to be maintained will be geared to the ongoing profitability of the livestock sector (primarily meat markets).

Legume pastures also confer benefits to the following cereal crop in the rotation, providing much of the nitrogen (N) demand of the crop and increasing grain protein levels.

Environmental outcomes

Integrated weed management (IWM) is an important consideration for sustainable cropping systems. This project has demonstrated that the inclusion of a pasture phase within cropping systems provides an effective and profitable strategy for managing herbicide resistant weeds. The challenge is to ensure livestock production systems do not degrade the soil resource. Bringing livestock back into the system does provide opportunities to consider other environmentally sound practices, for example, establishing non viable cropping country to perennial pastures for hydrological benefits and soil erosion management.

Social outcomes

The development of effective and profitable strategies to manage herbicide resistant weeds provides landholders with viable alternatives to current rotations and systems that are under pressure. These strategies provide alternatives that will maintain profitable farming businesses that support a wide range of agribusiness industries and rural communities. Mixed farming systems that incorporate livestock create a diversity of income streams and are likely to be lower risk in the face of climatic and economic uncertainty.

Achievements/Benefits

Background

Intensive cropping systems are the dominant land use in the northern wheatbelt of WA. Such systems rely heavily on selective herbicides for weed control. This has resulted in the emergence of herbicide resistance in many weed species that poses a threat to the continued profitability of this system. Incorporating short pasture phases into crop rotations provides the possibility to employ weed control strategies not available during the crop phase. This has the potential to maintain profitability while increasing the sustainability of farming systems in the northern wheatbelt.

The project had two main objectives:

(i) The first was to develop and test phase pasture systems to fit into farming systems in those areas of the northern wheatbelt of WA where continuous cropping is currently the dominant land use.
(ii) The second aim was to test the field response of newly available pasture legume varieties to the range of available herbicides likely to be important in phase systems.

Achievements

Output 1 - Development and assessment of phase pasture systems

This task represented the major component of the project and focused on investigations into pasture and crop sequences, pasture establishment issues, alternative weed control strategies and economic analysis.

Long term rotation trials (Attachment 1)

Two large field trials examined a range of pasture and crop sequences, including traditional self-regenerating pasture rotations and strategic short (sacrificial) pastures (termed phase pastures). The trials were managed over four years and measurements of annual ryegrass populations, legume persistence and subsequent crop performance were taken.
Crop - pasture sequences
The persistence of hard-seeded annual pasture legumes in self-regenerating rotations is questionable when high levels of weed control need to be achieved in every season. Where pasture seed set is compromised and regeneration after several years of cropping is required, legume densities are unlikely to be high enough to provide a productive pasture. Casbah biserrula and Charano yellow serradella offer the best prospects for success in these systems because of the capacity to form persistent seed banks - and both species allow for novel weed control strategies to be employed in the pasture phase (discussed below). The hard seeded French serradellas (Erica and Margurita) did not persist as well under grazing in the rotation trials as they did in ungrazed small plot trials (Attachment 3). This may have been due to their use as a component of legume mixtures in the rotation trials, rather than as pure stands.

Sacrificial legume pastures of one to three years duration provide the best means of achieving a pasture phase in which high levels of weed control and a high legume component for rotational benefits can be achieved. It is a simple system to manage and weed control is less likely to be compromised.

Weed Control
Hay freezing pastures (sometimes referred to as brown manuring) was the most successful and consistent means of reducing annual ryegrass populations (85-100% efficacy). Spray-topping also provided high levels of weed control, but it was not as consistent as hay freezing (58-92% efficacy), the timing of the application and the finish of the season both impacting on its effectiveness. If spray topping is to be utilised, consideration should be given to a dual application - one at early flowering and one at late flowering - to reduce the risk of both the season and an inappropriate timing of chemical application reducing the effectiveness of weed control. Hay cutting was effective for prevention of weed seed-set, especially when combined with hay freezing to control regrowth. The use of grazing on its own for weed control proved to be ineffective with the timing and grazing pressures applied during this study.

One area of concern highlighted by this project is the ability of annual ryegrass populations to quickly return to very high numbers once there is a return to cropping. For example, at the Mingenew site after three years of hayfreezing Cadiz10, annual ryegrass numbers were reduced to two plants/m². After one year of wheat (that was a very good season for cropping and annual ryegrass), annual ryegrass numbers rebounded to 1,800 plants/m². This quick recovery of weed populations in the cropping phase highlights the need to control annual ryegrass in every phase in every year. The initial concept with phase pastures was to have a two or three year pasture phase and then, once on top of weed populations, return to four or five years of cropping. However, once in-crop weed control options become limited due to herbicide resistance, the quick recovery of weed populations may mean that this type of rotation may no longer be feasible. Integrated systems with the complete range of weed control options in the cropping years (e.g. trifluralin1, targeted burning, seed catching, etc.) will be required. On the other hand, pasture phases followed by only one or two years of cropping may be necessary.

This research has also highlighted that annual ryegrass in the northern agricultural region of WA has a capacity for substantial levels of dormant seed to carry over from year to year. This level of dormant seed would seem to be higher than the 15-20% figure often referred to after one summer, with some seed possibly carrying through to the third season. This carry over of dormant seed appears to assist the rapid recovery of annual ryegrass numbers in the cropping phase.

Crop performance
Crop performance was highly influenced by annual ryegrass density, with increases in annual ryegrass numbers of 100 plants/m² reducing wheat yields by approximately 1t/ha. This relationship was dependent on the season and varied from year-to-year. In 2003 at Chapman Valley in a high potential crop (4t/ha), annual ryegrass numbers of 100 plants/m² resulted in a reduction in yield of 2t/ha. This variance from season-to-season and site-to-site seemed to be related to growing season rainfall (CSR) and the yield potential of the crop. In seasons where the end of season rainfall was low, competition with annual ryegrass had a large impact on yield. Where end of season rainfall was more favourable, the impact of competition from annual ryegrass was reduced and larger numbers of annual ryegrass could be sustained in the crop without huge reductions in yield. Cereal grain yields were consistently higher in the rotations with sacrificial pastures (of at least two years duration) as a consequence of more effective annual ryegrass control.

Economic Modelling (Attachment 2)
Use of the Simulated Transitional Economic Planning (STEP) model to analyse the economical potential of phase pasture systems described in this project show important benefits for the grains industry. In the presence of herbicide resistance, the use of phase pastures in the rotation has the potential to sustain or increase farm profits relative to continuous cropping (currently WL rotations). Livestock need to be included in these systems in order for them to be economically viable and their...
profitability is reliant on a buoyant meat market. The cost of pasture establishment and management and the opportunity cost of having the pasture phase out of production for cropping necessitate the use of livestock to generate an income stream on that part of the farm. The inclusion of pasture phases without livestock creates a drain on the productivity of the rest of the farm, usually resulting in a negative financial position. Two assumptions that will need to be validated in order for phase pasture systems to be implemented in the northern agricultural region of WA are that:
1) Grazing pressures of 5-6 dry sheep equivalent (DSE) per winter grazed hectare (WGha) can be achieved in the pasture phase
2) Large numbers of livestock can be carried on sandplain farms without creating major problems for soil erosion and other sustainability issues.

Alternative weed control (Attachment 4)
This project carried out two grazing trials on biserrula pastures to examine the effect of preferential grazing on weed control (exploiting differences in the acceptability of biserrula and weeds to sheep). One was extremely successful, achieving almost 100% weed seed-set control, highlighting the potential of preferential grazing as an alternative to weed control with herbicides. The second trial was less successful and suggests that further work should be undertaken to refine the management of this strategy. It appears that unless continuous grazing pressures are applied during the reproductive phase of the weeds (as occurred in the first trial but not the second), seed-set control of the weeds will be less effective.

Pasture Establishment (Attachment 5)
Eastern Star clover is a new pasture legume species under development which has a peculiar delayed germination character and the capacity to grow rapidly in winter. Several trials were conducted to investigate the potential of delayed sowing in Eastern Star clover to enhance weed management, yet still provide a productive legume-based pasture. In one trial, delaying sowing from mid-May to mid-June had no impact on final pasture biomass production or seed yield (SY). This should offer opportunities for good weed control with one or more applications of non-selective herbicides, without seriously compromising seed set or biomass production of the legume. In a second trial, delayed sowing into high annual ryegrass populations was less successful, as soil disturbance at sowing stimulated new annual ryegrass germination regardless of the time of sowing. Further development of this strategy is required.

Delayed germination in some legumes has created an opportunity for weed control in regenerating pastures using an early application of non-selective herbicide. It relies on the fact that most of the weeds will emerge (and be controlled) before the pasture legume germinates. Early indications are that this technique can be successful in Eastern Star clover and yellow serradella, but it needs further refinement before it can be promoted as an effective weed management tool.

Additional small plot trials were carried out early in the project to examine the impact of issues like nutrition (Attachment 6), seeding rates and dry sowing on pasture establishment. These trials were affected by dry seasonal conditions in 2000 and 2002, however some principles for establishing pastures were developed and extended to growers through trial reports (Attachment 5).

Output 2 - Herbicide tolerance of new pasture legumes
Two highly successful field trials were carried out to assess the herbicide tolerance of newly released pasture varieties and varieties that are close to commercialisation.

Field Trials (Attachment 7)
Herbicide tolerance varied widely between species of pasture legume. Growers and agronomists need to make careful decisions when choosing herbicide treatments. Most varieties have a number of safe herbicide options, but they are often expensive. Key findings included recognition that Erica and Margurita French serradella have very similar tolerances to Cadiz. Spinnaker® PSPE, Raptor® and Kerb® were the three safest chemicals across the pasture legumes tested. Broadstrike® was safe on most varieties, with the exception of Casbah biserrula. Spinnaker® at a rate of 250ml/ha PSPE was one of the safer treatments for Casbah and yet the same treatment PE was very damaging. This work has contributed to the collective knowledge of the herbicide tolerance of annual pasture legumes and sufficient data may now be available for chemical companies to consider updating their product labels.

Extension of project outputs
Extension of this work to growers and agribusiness was successfully carried out throughout the project. Grower field days
were held at most trial sites. Reports were published in the proceedings of Agribusiness Crop Updates in 2002 and 2004, Regional Crop Updates, Northern Agricultural Region Trial and Demonstration Reports and the Mingenew Irwin Group grower groups trial and demonstration reports. Recent surveys of pasture legume establishment indicate a resurgence of interest in pastures for the northern wheatbelt of WA and a high proportion of serradella seed is being sold into this region. This is consistent with the need to combat the rapid development of herbicide resistance in annual ryegrass and wild radish in this region.

A scientific paper is planned to describe the impact of various pasture crop sequences on changes in annual ryegrass populations through time. The data collected on herbicide tolerance of pasture legumes is also being consolidated with other experimental results in related project work (GRDC Project DAW00031).

Other research

A number of research and development (R&D) opportunities have emerged from this project.

Studies in collaboration with growers implementing phase pasture rotations are required to identify and address the constraints for successful adoption of these systems on a farm scale. Reducing the cost of pasture establishment is highly desirable and attention should be given to novel strategies, such as under-sowing cereal crops with hard seeded legumes that germinate in the following year when the pasture phase is required.

Selective grazing with sheep on biserrula pasture is likely to be of considerable value in intensive cropping systems. Refining the management for this strategy and assessing how it may fit into farming systems requires further investigation. Good progress in this regard has been made in GRDC Project DAW32, but further work is required to develop complete animal production packages for biserrula and to research the link between biserrula and photosensitivity in grazing sheep.

The dormancy of annual ryegrass seed appears to be greater than has previously been documented allowing considerable carryover of seed between years. Further studies on the longevity of annual ryegrass seed, factors that may affect seed dormancy (grazing, temperature and moisture levels at the time of seed production) and triggers for germination are required. This should build on the work reported by Steadman and Ellery (2004), 14th Australian Weeds Conference, Wagga Wagga.

Early non-selective weed control in pasture species with delayed germination (like Eastern Star clover) appears to be a novel management strategy that can result in relatively weed free (legume dominant) pastures. Refining the management of this strategy and assessing the impact on weed populations and seed banks requires further investigation.

For phase pasture systems to be economically competitive with current systems, grazing pressures of 5-6 DSE/WCha will need to be achieved and large numbers of livestock will need to be carried on sandplain farms without creating major soil degradation problems. Investigations need to be undertaken to determine if such grazing systems are feasible and sustainable.

Many of the safest broadleaf herbicides in legume pastures are very costly. Tolerance to broad spectrum herbicides like simazine®, diuron® and MCPA® would be highly desirable. The development of low cost herbicide options, perhaps through a targeted plant improvement program, seems warranted.

Intellectual property summary

The output from this project is in the form of information, rather than products, and is not readily captured by commercialisation processes. IP management will be in accordance with DAWA, GRDC and Western Australia state government IP policy.

Additional information

Attachment 1
Blake, A (2001). Utilising Phase Pastures for the Management of Ryegrass Populations. Published in Northern Agricultural Region Trial and Demonstration Reports
Attachment 2

Attachment 3
Blake, A. and Lauritsen, N. (2002). Serradella Variety Trial. Published in Northern Agricultural Region Trial and Demonstration Reports
Rogers, D. and Lauritsen, N. (2004). Regenerating Hard Seeded Serradella. Published in Northern Agricultural Region Trial and Demonstration Reports.

Attachment 4

Attachment 5
Blake, A. (2001) Establishing annual pasture legumes. Published in Northern Agricultural Region Trial and Demonstration Reports.

Attachment 6

Attachment 7